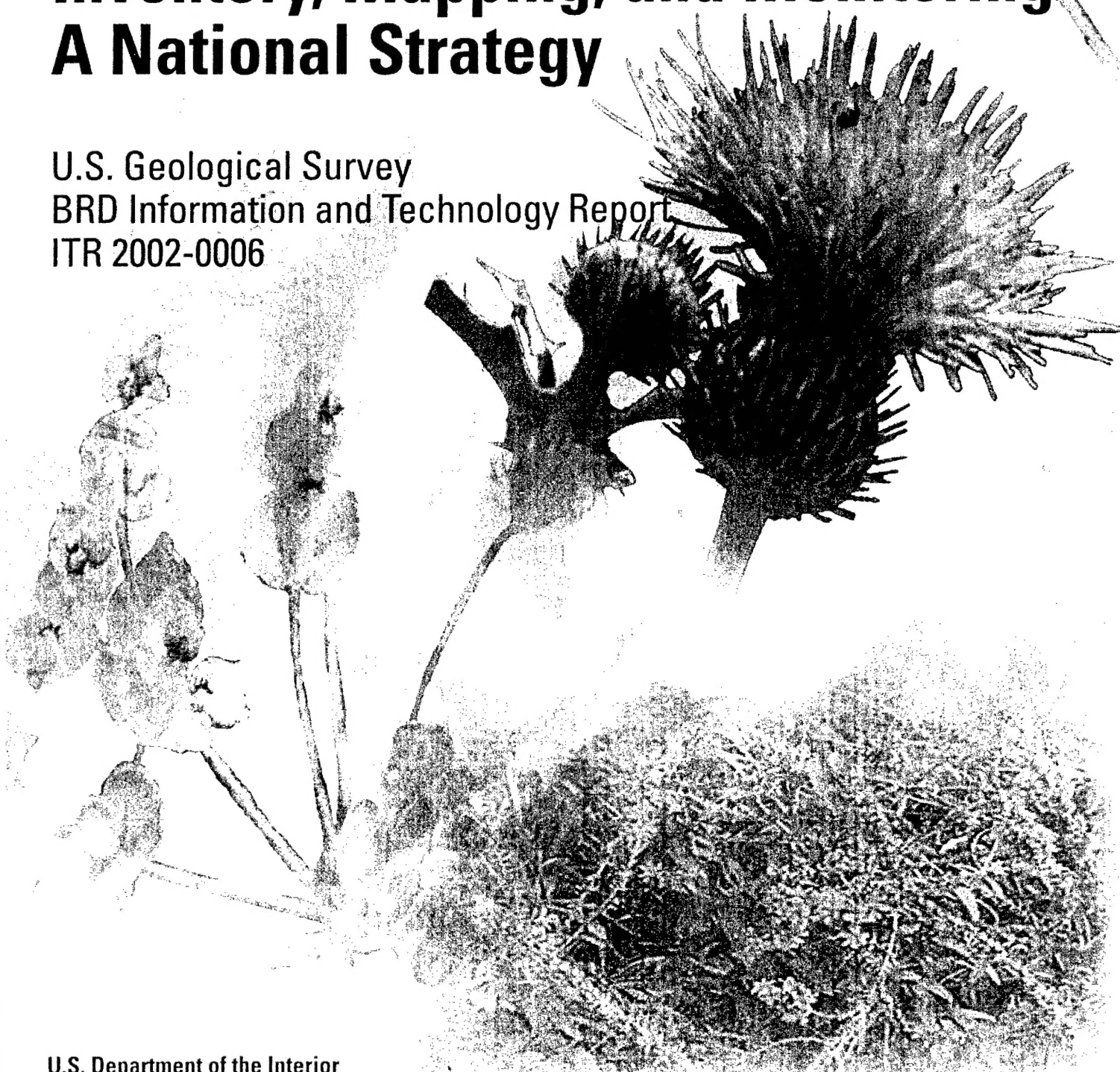


Workshop Report—Office of the Regional Biologist, Central Region

Invasive Plant Species Inventory, Mapping, and Monitoring— A National Strategy

U.S. Geological Survey
BRD Information and Technology Report
ITR 2002-0006



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Inventory, Mapping, and Monitoring—
A National Strategy

By Larry Ludke, Frank D'Erchia, Jan Coffelt, *and* Leanne Hanson

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Contents

Executive Summary	1
Introduction	1
Findings and Recommendations	2
Workshop Findings	2
Recommendations	2
Recommendation Discussion	2
Budget Initiative	2
Partnerships	3
Federal Lands Invasive Plant Inventory, Mapping, and Monitoring Coordination Team.....	3
National Institute of Excellence	4
Workshop Minutes	4
The National Biological Information Infrastructure (NBII).....	4
The Lacreek National Wildlife Refuge Pilot Project	5
Science Needs of Federal Land Managers.....	6
U.S. Fish and Wildlife Service.....	6
National Park Service	7
Bureau of Land Management.....	8
U.S. Department of Agriculture—Agricultural Research Service	9
Bureau of Indian Affairs	9
Bureau of Reclamation	9
References Cited	10
Appendix A—Results from Breakout-Group Discussions	11
Inventory Breakout Group	11
Mapping Breakout Group	12
Monitoring Breakout Group	13
Appendix B—Workshop Participants and Report Contributors	15

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Workshop Report

Invasive Plants

Inventory, Mapping, and Monitoring— A National Strategy

By Larry Ludke, Frank D'Erchia, Jan Coffelt, and Leanne Hanson¹

With contributions by Tom Owens, Tom Stohlgren, Gary Waggoner, Virginia Burkett, Larry Handley, Carol Dawson, Phil Dittberner, Julie Stumpf, Geneva Chong, Jennifer Gaines, and Karl Brown

Executive Summary

America is under siege by invasive species of plants and animals, and by diseases. The current environmental, economic, and health-related costs of invasive species could exceed \$138 billion per year—more than all other natural disasters combined. Notorious examples include West Nile virus, Dutch elm disease, chestnut blight, and purple loosestrife in the Northeast; kudzu, Brazilian peppertree, water hyacinth, nutria, and fire ants in the Southeast; zebra mussels, leafy spurge, and Asian long-horn beetles in the Midwest; salt cedar, Russian olive, and Africanized bees in the Southwest; yellow star thistle, European wild oats, oak wilt disease, Asian clams, and white pine blister rust in California; cheatgrass, various knapweeds, and thistles in the Great Basin; whirling disease of salmonids in the Northwest; hundreds of invasive species from microbes to mammals in Hawaii; and the brown tree snake in Guam. Thousands of species from other countries are introduced intentionally or accidentally into the United States each year. Based on past experience, 10–15 percent can be expected to establish free-living populations and about 1 percent can be expected to cause significant impacts to ecosystems, native species, economic productivity, and (or) human health. The time has come for scientists, managers, and stakeholders affected by invasive species to rally together to build better systems for invasion prevention; improved early detection of new invaders; tracking established invaders; and coordinated containment, control, and habitat restoration.

To begin addressing such an enormous task, this

workshop—the first in a series—focused on specific invasive-plant-species issues. Phase 1 will focus on the inventory and monitoring of invasive plant species, with an emphasis on developing a consistent and standardized method of mapping vegetation communities, both native and non-native. Additional workshops will focus on other invasive species (e.g., animals, diseases, etc.), and other science needs (e.g., appropriate use and effects of mechanical or biological treatments).

Introduction

This document represents the efforts of an interagency group of Federal scientists and managers. Over the course of several months, through meetings and individual requests from U.S. Geological Survey (USGS) partners and clients, the problems associated with invasive plant species were identified as priority concerns of Federal land managers. The USGS Central Region, in response to those concerns, organized this workshop. Participants included representatives from the U.S. Fish and Wildlife Service (USFWS), the Bureau of Land Management (BLM), the National Park Service (NPS), the Bureau of Reclamation (BOR), the Bureau of Indian Affairs (BIA), the U.S. Department of Agriculture Forest Service (FS), and the Department of Interior National Invasive Species Council (DOI-NISC), as well as USGS scientists with expertise in inventory, mapping, and monitoring of invasive plants.

Different agency missions result in different needs and applications of information to address invasive-plant-species science needs. USGS is a science agency. It does not manage lands or species but rather is responsible for providing the scientific information, research, and technical assistance needed by other Federal land-management agencies to effectively manage their trust responsibilities. By contrast, USFWS,

¹ U.S. Geological Survey, Central Region, Office of the Regional Biologist, Lakewood, Colo.

BLM, FS, and NPS all manage Federal lands and the species that occur on them. The USFWS mission also extends beyond USFWS-managed lands, due to its statutory responsibilities for endangered and migratory species. In addition, varying land-ownership patterns across the country present different opportunities and needs for research. The invasive-plant-species science and information needs presented in this document may result in research being conducted on lands managed by DOI agencies, other Federal agencies, and State or local agencies.

The workshop's assigned task was to develop a strategy for addressing Federal agency invasive-plant-species science and information needs. More specifically, we wanted to develop a comprehensive understanding of the invasive-plant-species inventory, mapping, monitoring, and science needs of the Federal land-management agencies.

Findings and Recommendations

Workshop Findings

- Each participating agency (see Appendix B) listed invasive plants as one of their highest concerns.
- Agency reports had a common theme of identifying a need to inventory what invasives are present on lands under their purview, and quantifying the abundance and distribution through various mapping (photo interpretation, remote sensing) techniques to develop a GIS database.
- Monitoring is considered a critical post-treatment component to assess effects of management actions and evaluate increases or decreases in the spread of invasives.
- Modeling is important to predict areas to monitor for early detection of invasive plants.
- A standardized invasive-species classification system and consistent methodology is critical for national assessments and repeatability.
- All agreed that a multidisciplinary budget initiative was needed to address an issue of this magnitude. The USGS will initiate the budget proposal, with the other stakeholder Federal agencies supporting the justification.
- There is general agreement that the USGS has the unique capability to provide inventory and mapping services, develop monitoring protocols and techniques, and conduct research activities needed to address this critical issue.
- There is a high priority on (1) early detection to keep invasive plants in check, (2) development of models to predict where to look for invasives, and (3) an understanding of the ecology of invasive plants through research to help prioritize and guide management actions.

Recommendations

- Develop and implement an FY 2004 USGS *Budget Initiative* that addresses the Federal land managers invasive-plant-species management-research and information issues, to be promoted and supported by a *partnership* of Federal land-management agencies.
- Establish a *Federal Lands Invasive Plant Inventory, Mapping, and Monitoring Coordination Team* composed of a representative named by the USGS and representatives named by counterparts in the partner Federal land-management agencies.
- Establish a USGS Invasives Plant Species Inventory, Mapping, and Monitoring “*National Institute of Excellence*” to coordinate science and information activities identified in the budget initiative in support of Federal land-management agencies.
- Establish a *National Biological Information Infrastructure* (NBII) thematic node focusing on an invasive species to increase accessibility to integrated invasives information from many sources to support improved decision making by land managers and others.

Recommendation Discussion

Budget Initiative

The inventory, mapping, and monitoring of invasive plant species is a high priority for all of the Federal land-management agencies represented at the workshop. The capabilities exist within USGS to conduct needed science activities as identified in this document. Through implementation of this initiative, the Federal land-management agencies will be better prepared to implement sound management strategies. These agencies have identified the importance of invasive-plants issues and have addressed them as fully as possible with currently allocated funds, but the resources fall far short of what is necessary to adequately address this issue. In addition, research to address invasive-species problems is fragmented and would benefit from a strong, unified science approach to information discovery, interpretation, and delivery.

Based on their knowledge of management, monitoring, and research needs, the workshop identified the need for a budget initiative adequate to support both the scientific-research needs as well as the management applications that would be required to address the invasive-plant-species inventory, mapping, and monitoring needs. The funding could be used to provide for USGS activities that include (1) development of an standardized inventory system to assess the current status of invasive plants, (2) implementation of a standardized GIS-based mapping program to characterize natural, as well as invasive, plant communities, (3) development of a standardized monitoring protocols, (4) development of spatial and temporal models that can be used for early detection of invasive-plant-

species outbreaks, as well as being applicable to other aspects of inventory, mapping, and monitoring, (5) identification of other data and information needs and of research requirements to support Federal land-management agencies' actions, and (6) design, development, and implementation of a web-based information management system to provide access to integrated spatial and non-spatial data and information related to invasive species (initial efforts will be an expansion of the Invasive Species NBII currently under development).

Additionally, funding would be available to Federal land-management agencies for activities that include: (1) testing of management options for removal of invasive plants and restoration of native-plant communities for habitat improvement, (2) implementation of various management applications to halt the spread of invasive species and eradicate new invasive species through early-warning techniques, (3) implementation of the inventory and monitoring techniques and protocols as developed by the USGS, and (4) assistance in GIS data collection and database development, field work, and other collaborative activities.

Workshop participants recognize that both USGS and the Federal land-management agencies may be allocating some existing funds or planning budget initiatives to address invasive-plant-species information and management needs. However, the current level of these existing funds will not begin to address the current shortfall in funds for invasive plant species. In addition, in the current restrictive budget climate, it would place these Federal land-management agencies in the position of postponing other priority programs to supplement an invasive plant effort. Therefore, we strongly recommend the development of a Federal Lands Invasive Plant Species Inventory, Mapping, and Monitoring budget initiative for FY 2004. This funding would be used to address the issues identified in this report and to support existing management activities to identify which invasive plant species are on Federal lands, the extent and seriousness of the invasions, mapping new invasive plant outbreaks, and how to monitor for successful treatment and management actions to mitigate the effects of the invasive plants on critical habitat. We recommend the following approach to this initiative:

1. Provide funding to the USGS to (a) conduct the science and technical assistance necessary to accurately inventory, map and monitor invasive plant species across the Nation, (b) provide an authoritative, collective, integrated resource of web-based information accessible to Federal land managers and the public through the NBII node, and (c) conduct research to identify the most appropriate eradication and management applications.
2. Provide funding to the partnership of Federal land-management agencies to implement the most effective management resulting from the scientific research of the USGS.

Development of a budget initiative of this magnitude will require additional details about the distribution of funds and how that money will be managed. We recommend that a Federal Land Invasive Plant Species Coordination Team be established and assigned responsibility to further develop the budget initiative

and generate a Memorandum of Understanding. Furthermore, a USGS "National Institute of Excellence" will be designated to coordinate all inventory, mapping, and monitoring activities.

Partnerships

The participants in this workshop recognize that development of a comprehensive approach to invasive species requires a broader range of partnerships beyond the Federal land-management agencies represented at the workshop. Partners should include other Federal agencies, State wildlife and natural resource agencies, broad-based interagency organizations, academia, and private industry. In addition, because this issue has enormous economic impacts, we have the opportunity to collaborate with the Department of Interior National Invasive Species Council and other national and international organizations. In addition to the DOI National Invasive Species Council, a collaborative multi-agency effort, known as the Federal Interagency Committee for the Management of Noxious and Exotic Weeds (FICMNEW, see <<http://refuges.fws.gov/FICMNEWFiles/FICMNEWHomePage.html>>), was established under an MOU signed by 17 Federal agencies and is responsible for coordinating a Federal Government approach for the management of weeds (Federal Interagency Committee for the Management of Noxious and Exotic Weeds, 2002). This includes providing information about agency needs and making recommendations to departmental leadership on research, technology transfer, and management actions. The Federal agencies are cooperating to achieve the advancement of knowledge and skills, good land-stewardship practices, and public awareness of noxious weed issues and management. The Federal Lands Invasive Species Inventory, Mapping, and Monitoring Coordination Team will coordinate all activities with both the National Invasives Species Council and FICMNEW and serve as a subcommittee focused on the issues of this workshop. Although making recommendations regarding specific cooperative actions is beyond the scope of this strategy document, we urge Federal land-management agencies to communicate and collaborate with these potential cooperators as much as possible.

Federal Lands Invasive Plant Inventory, Mapping, and Monitoring Coordination Team

An initiative that involves cooperation and collaboration among all Federal land-management agencies with interests in invasive species will require some minimal infrastructure to facilitate communication and ensure that the interests and needs of all agencies are recognized. We recommend the naming of a Federal Lands Invasive Plant Species Coordination Team composed of a representative named by the USGS and representatives named by counterparts in the Federal land-management agencies (e.g., FWS Regional Directors, BLM

State Directors, NPS Regional Directors, etc.). This team would oversee invasive plant activities in their individual agencies, coordinate activities and initiatives among agencies, represent the importance of invasive-plant-species information needs and conservation to the Department, and assist in the promotion and refinement of the proposed budget initiative.

National Institute of Excellence

The USGS is in a unique position to strengthen our Nation's ability to effectively and efficiently manage invasive plant species by coordinating the separate approaches of the various Federal land-management agencies through a "virtual," distributed National Institute of Excellence for Invasive Plant Species Inventory, Mapping, and Monitoring. Currently, invasive-species issues are very important for most land-management agencies, but funding for work by individual agencies is insufficient to meet their needs and the full benefits of existing work are not felt across or even within agencies. This is in part because there is no coordination of a research agenda, research findings, or existing information on invasive species. As a Nation, we cannot afford to lose the battle against invasive species, which already are estimated to cost the Nation \$138 billion annually. By fully coordinating and integrating the efforts of multiple USGS disciplines with those of other Federal agencies, and partnering non-Federal organizations, through a virtual National Institute of Excellence, we will greatly improve our ability to gather, coordinate, analyze, and use the information needed by researchers and managers to protect our resources. Providing continuous integrated access to high-quality, distributed data and information through the web will also be a major function of this proposed National Institute of Excellence.

One existing activity that could provide a starting point for a National Institute of Excellence is the National Institute for Invasive Species Science (NISS) based at the Fort Collins Science Center (FORT), Fort Collins, Colo. Currently the NISS is a consortium of individual research projects (11) that leverage their research dollars (six funding agencies, including the Joint Fire Science Program) through coordinated interactions (e.g., data sharing and common sampling standards). The recent establishment of a National Biological Information Infrastructure (NBII) Invasive Species Node for the NISS will further strengthen its ability to manage and communicate information to resource managers and the public at large over the web. It will also provide enhanced access to biological information across the web by using the Integrated Taxonomic Information System (ITIS) taxonomic authority source. The ITIS integrates scientific names, synonyms, and common names in multiple languages to facilitate more comprehensive queries over a variety of search engines. Explicit coordination with the Earth Resources Observation Systems (EROS) Data Center and the USGS-NPS Vegetation Mapping Program, for example, expands the virtual size of the CISS by leveraging other existing USGS resources. The

envisioned National Institute of Excellence would build on this approach to provide, for the first time, coordination of the relevant research activities of this and other regional centers through a cooperative matrix-management approach rather than requiring all researchers to be organizationally and programmatically collocated.

A first step in the creation of a National Institute of Excellence for Invasive Plant Species Inventory, Mapping, and Monitoring would be the hiring of a full-time project coordinator and a full-time data/network manager for facilitating both information-gathering and dissemination through existing frameworks (e.g., the NBII, the EROS Data Center, the USGS-NPS Vegetation Mapping Program, and many others). This National Institute of Excellence would provide a valuable model for developing similar centers of excellence for dealing with invasive animals and diseases, or it could be expanded to encompass the full array of invasive-species concerns.

Workshop Minutes

The rest of this report contains information presented at the workshop, including summaries of needs presented by the Federal land-management agencies represented and reports of the breakout sessions.

The National Biological Information Infrastructure (NBII)

The National Biological Information Infrastructure (NBII) (<<http://www.nbii.gov>>) is a broad, collaborative program to provide increased access to data and information on the Nation's biological resources. The NBII was initiated in 1993 based on the recommendations of a special commission convened by the National Research Council and published in the report "A Biological Survey for the Nation." More recently, in 1998, a team of internationally renowned scientists, the Biodiversity and Ecosystems Panel of the President's Committee of Advisors on Science and Technology, endorsed the NBII and detailed the need for developing a next-generation NBII or NBII-2, in their report "Teaming with Life: Investing in Science to Understand and Use America's Living Capital."

Today, work on the next-generation NBII is underway. One of the key components of the next generation NBII is a system of nodes that is being developed to ensure a cooperative network of broad partnerships and relevant, credible information from all sectors of society. The nodes will be virtually interconnected NBII entry points that, taken together, will form the NBII on the web. The establishment of this network of nodes will help the NBII to provide a vast community of users with rapid access to information on the Nation's biological resources.

Three node types are currently being developed—

regional, thematic, and infrastructure—and offer a range of NBII functional capabilities for addressing content and technology issues.

- *Regional*.—Focuses on resource issues in a geographical setting and represents a regional approach to local data issues, data collectors, and owners.
- *Thematic*.—Concentrates its efforts on a particular biological issue, such as avian (bird) conservation, to provide access to that topic on a national level.
- *Infrastructure*.—Develops and shares the technology and information-science capabilities, software, standards, and services that apply to all nodes and other components of the program to build the seamless NBII network.

Each type of node provides support in several areas including:

- Analysis and synthesis tools
- Technology support
- Data warehousing
- Data mining
- Data dissemination
- Interoperability
- Collaboration
- Training and education

An Invasive Species thematic node—currently under development—will provide access through a single web portal to a vast array of distributed data and information about this critical issue facing the Nation. The plans are for this node to increase accessibility to integrated invasives information from many sources to provide scientific support for improved-decision making by land managers and others. The first release of the website is expected in Spring 2002 (see: <<http://invasivespecies.nbii.gov>>).

Development of the Research Applications portion of this new NBII Invasive Species website is an important component of the overall concept. Beginning in 2002, a team led by Dr. Tom Stohlgren at FORT, will develop local-, regional-, and national-scale maps of invasive species, and identify priority invasive species, vulnerable habitats, and pathways of invasion. New spatial models will be made available to researchers, land managers, and educators to assess current distributions of invasive species, potential distributions, and levels of uncertainty associated with ecological-forecasting models on the predicted spread of invasive organisms.

Additional NBII nodes contributing invasive species information include:

- California Information Node
- Pacific Basin Information Node
- Fisheries and Aquatic Resources
- Central Southwest/Gulf Coast Information Node
- Northeast Urban Biodiversity Information Node (currently under development)

NBII also assisted the National Invasive Species Council in establishing its initial integrated website on invasive species (<www.invasivespecies.gov>), which organized a large

amount of invasive-species information that existed in numerous, scattered locations across the internet. The council is now anticipating designing and serving its own customized website to reflect the interagency program it is directing.

The Lacreek National Wildlife Refuge Pilot Project

Inventory Terrestrial Invasive Weed Species and Distribution on Lacreek National Wildlife Refuge Through a Geographic Information System (GIS) Initiative.

The United States Fish and Wildlife Service (USFWS) mission includes a responsibility to protect wildlife habitat as well as native plant communities on National Wildlife Refuge lands. However, the health of refuge ecosystems is under attack by invasive non-native plants (weeds). Although there are many strong efforts to control invasives, land managers must know the extent of the weed problem and whether their current management strategies are working. Mapping and monitoring are weak links in many weed-management plans because resources are dedicated to ground-control work. Specifically, USFWS managers need to know which species of terrestrial weeds are invading refuge lands, where the invasions are occurring, where invasions may occur in the future, where weed-control activities are occurring, and the results of those activities. In addition, the Service needs to adopt standardized mapping techniques and refuges need technical assistance in developing and managing spatial data.

Geographic Information Systems (GIS) technologies answer many of these needs. GIS can display maps of weed infestations and relatively natural vegetation communities. These maps can depict areas where control and prevention measures have occurred and the results of those measures. GIS can also be used to develop predictive models of where future invasions may occur. This information will enable refuge managers to make better decisions regarding progress toward eliminating weeds and providing more natural habitat to achieve wildlife management objectives. To achieve this goal in USFWS Region 6, a pilot project to inventory and map the weeds at Lacreek National Wildlife Refuge in South Dakota was initiated in 2001. The work will be completed by September 2002.

Methodology.—Vegetation communities are being sampled, described, classified, and mapped using the methodologies developed by the USGS-NPS Vegetation Mapping Program (<<http://biology.usgs.gov/npsveg>>) and now extended to USFWS refuges in Region 6, including Lacreek NWR. The vegetation communities will be (1) sampled, described, and classified using field-plot methods and classification methods by qualified ecologists, and (2) mapped using aerial photo interpretation by qualified photo interpreters and transferred into a geospatial database. The products developed by this work form the basis for the invasive plants sampling. The new vegetation map will be used to stratify the refuge into

common and rare habitat types vulnerable to invasion (e.g., riparian zones, wetlands). A random subset of sample units in each stratum (habitat type) will be selected for study in conjunction with the accuracy assessment plots. Trained botanists will establish larger, multiscale vegetation plots to quantify patterns of native and exotic species richness and cover and soil characteristics following peer-reviewed and tested methods (see Stohlgren and others, 1997, 1998, 1999). Findings of several highly invasive species or many noxious species, or extensive outbreaks of any invasive species of management concern, may require additional survey points.

Products.—Products from the vegetation mapping project include plot data in a standardized database format, vegetation community classification, descriptions, a dichotomous field key of vegetation communities, geospatial data sets of the communities, hard-copy maps, accuracy assessment, and methods report. Products from the invasive plots include an MS Access database linked to ArcView to manage, store, analyze, and display information on native and exotic plant species, exotic-species distributions, soil characteristics, and various geographic data. This information becomes the input for predictive geospatial models and analytical techniques to set invasive-species-control activities. It establishes (1) a set of rigorous long-term monitoring plots to evaluate the spread of invasive species, and (2) control and restoration efforts as a basis for adaptive management.

Partnership and roles.—NatureServe (formerly ABI) will review the vegetation classification to ensure that it meets national standards and will incorporate the classification into the evolving National Vegetation Classification System being developed in conjunction with the Federal Geographic Data Committee. The invasive-species methods were designed to provide maximum comparability to other regional and national invasive-species-monitoring programs including several USGS landscape-scale surveys in National Parks and Monuments, and the USDA Forest Service's Forest Health Monitoring Program. Thousands of plots with similar data provide an incredibly strong capability to synthesize data at regional and national scales as a comparison to local conditions at specific refuges. This work could easily be expanded regionally and nationally.

Science Needs of Federal Land Managers

A briefing was provided by representatives from each of the Federal land-management agencies present at the workshop (see Appendix B). This section contains information compiled by the speakers to provide workshop participants with a broad overview of issues related to invasive plant inventory, mapping, and monitoring. Although this workshop was regionally based, the briefings included national issues. To ensure a national perspective, the draft initiative that will be developed as an outcome of this workshop will solicit a broad national review across all Federal agencies involved (see Recommendations section).

U.S. Fish and Wildlife Service

Responsible for managing Federal land holdings exceeding 100 million acres, the U.S. Fish and Wildlife Service (USFWS) is faced with an enormous problem of addressing a backlog of science and information needs related to invasives. The current backlog exceeds \$1 billion, with about \$15 million related to invasives. Under these conditions, the USFWS can only react to immediate and highly visible problems that can be directly considered economic and environmental emergencies. The most important questions raised regarding the real problem with invasives include how many acres are affected and what non-natives species are coming? The USFWS has a need for more scientific information that can be used to develop management tools. The agency specifically needs rapid, accurate, adaptable landscape and site-specific predictive capabilities. Many public issues arise due to invasive species, as well as critical habitat-management issues, and the USFWS would like to apply adaptive-management tools and techniques. There is a strong tie between wildlife recreation and invasives. Many of the mandated activities of the USFWS are related to invasive issues, such as regulatory, law enforcement, border issues, adjacent private landowners, and recreation.

In a May 2000 "Report on the State of Invasive Species Management," completed by the Region 6 Cross-Program Invasive Species Management Team, inventory and monitoring were identified as high priority needs.

Two specific needs identified were:

- Maintenance of a standard database to monitor the spread of invasives, and
- Development of a GIS system to *map, inventory and monitor*.

Additional needs identified included:

- Increasing the level of awareness of invasives across the field operations as well as the general public;
- Standardizing the inventory process;
- Developing a GIS-based spatial database of vegetation/invasive communities;
- Developing management links to such products as GIS databases as well as having an ability to relocate and monitor;
- Developing quality science for Invasive Pest Management strategies;
- Coordinating with partners, especially bordering Federal lands, as well as private land owners;
- Improving the ability of field staff to recognize invasives, (including training to improve awareness);
- Developing long-term monitoring;
- Improving the understanding of invasive plant ecology; and
- Developing control agents.

In summary, the USFWS expressed an urgent need for a standardized inventory and monitoring protocol for invasive plants, including products such as GIS databases using standardized classifications that are strongly linked to management actions and adaptive-management techniques.

National Park Service

The National Park Service (NPS) offered an overview of existing programs related to weed inventory and mapping as well as additional information and research needs.

A. Service-Wide Issues/Programs Related to Weed Inventory and Mapping

As a result of the *Government Performance and Results Act of 1993* (GPRA), NPS has established a Performance Management System. This system specifically identified a mission goal that required the NPS to report on issues related to the management of invasive exotics. The GPRA Goal 1a1B specifically states that by September 30, 2005, exotic vegetation on 6.3 percent of targeted parklands is to be contained.

Three problems identified were:

- Definition of "targeted" needed
- Accuracy of reporting
- Most parks lack complete baseline weed inventories and (or) no standard methods for defining an "Acre of Infestation."

Through the *USGS-NPS Vegetation Mapping Program*, mapping is primarily achieved by the use of aerial photography at a scale of 1:24,000 (or 1:12,000 for digital ortho mapping quads). The goal of vegetation mapping is to achieve 80-percent accuracy at the 1:24,000 scale. The minimum mapping unit used is 0.5 hectare. Vegetation mapping is done at the association level following the nomenclature adopted by the National Vegetation Classification System (NatureServe approach). Mapping projects are park specific and are driven by park goals and objectives within the overall program standards. Vegetation mapping work is verified through the use of reconnaissance/characterization plots to test accuracy of aerial photo interpretations.

There are several opportunities for the Vegetation Mapping Program to assist with weed mapping efforts:

- Provide additional training to field crews on weed identification so that they are better at detecting these species.
- Use the data gathered to help indicate areas with potential weed problems because, in most cases, the Reconnaissance Plots are not based on weed locations.
- Use vegetation maps for developing (stratifying) invasive species (flora and fauna) monitoring protocols and locations.

The limitations of the Vegetation Mapping Program in assisting with NPS weed mapping activities identified were:

- A lack of a specific focus on mapping weeds;
- Mapping activities and "ground-truthing" take a lot of time (typically 2–5 years per park to do all vegetation associations) depending on the complexity of the vegetation at a given park and the park's size;
- The Program is a one-shot documentation that establishes a baseline but lacks the funding to conduct long-term monitoring.

In 1999, the NPS announced a 5-year strategy, the *NPS Natural Resource Challenge*, to improve our abilities to manage natural resources within the parks. This strategy placed specific emphasis in three main areas: Inventory and Monitoring, Native and Endangered Species, and Non-Native Species.

Exotic Plant Management Teams (EPMT).—EPMT's, an initiative developed under the Natural Resource Challenge, began to assist the Service with addressing our invasive-species issues. These teams are based on a model demonstrated at Lake Mead and assist multiple parks within a specified geographic area with exotic plant management.

EPMT's have two primary functions:

1. To provide operational management of priority exotic plant species.
2. To provide training to host and partner park staffs in exotic plant identification, post-treatment monitoring, and safe application of management techniques to enable park staffs to assume responsibility for maintaining treated areas at an acceptable maintenance level.

EPMT's provide a critical service, however, this program is limited because its efforts are focused on control and management and not on the fundamental inventory and mapping of weeds, although some teams perform this function to a limited extent. This limitation often puts the Service in a position of providing management actions without having complete information on weed species and their locations to help us in ensuring that our actions are priority driven and serve the best purpose. Four teams were established in 2000:

- Chihuahuan Desert/Short Grass Prairie;
- National Capitol Region;
- Pacific Islands; and
- Florida Parks

Six additional EPMT's will be funded in 2002:

- Florida Partnership;
- Lake Mead;
- California Parks;
- Gulf Coast;
- Northern Great Plains; and
- Columbia Cascades.

The *Inventory and Monitoring Program* was initiated in 1992. This program established networks of parks, based primarily on their ecological similarities, therefore establishing the likelihood that they would have similar ecological parameters that need to be monitored. Primary goals of this program are:

- Document through existing, verifiable data and targeted field investigations the occurrence of at least 90 percent of species of vertebrates and vascular plants occurring in each park.
- Describe distribution and relative abundance for species of special concern (this can include exotic species).
- Provide baseline information needed to develop a long-term monitoring strategy tailored to specific park threats and resource issues. (Vital Signs Monitoring.)

B. Inventory and Monitoring Program Regional (IMR) Efforts

- Use of North American Weed Management Association (NAWMA) minimum mapping standards
- IMR Weed Mapping Natural Resources Protection Program Grant
- Draft IMR Weed Mapping and Database Development Guidelines

C. Individual Park/Network Efforts/Needs

The mapping system currently being used by the parks is inconsistent to the point where many parks are following the protocols of other organization such as the Montana Weed Inventory and Mapping System and the Southwest Exotic Plant Mapping Program.

D. Primary NPS Needs

- Baseline information—most park units lack good weed inventories.
- Development of efficient, statistically valid inventory protocols that address both spatial (large vs. small land areas) and temporal (short and long-term monitoring activities) needs. Especially for smaller parks—need to identify time- and money-efficient means that provide a reasonably adequate assessment of weed populations and changes over time. Also, need to tie into the I&M Biological Inventory and Vital Signs Monitoring activities.
- Greater research efforts on improving remote-sensing technologies for use in weed inventory and mapping activities.
- Identification and collection of data related to key environmental or ecological parameters that can help predict susceptibility of a large range of habitats to weed invasions (e.g., ecological modeling) and across the larger landscape.
- Development of monitoring systems to help quantify the impacts of invasive species on ecosystems.
- Development of a regional repository for weed inventory/mapping data that allows for landscape-level analysis of weed locations (centralized data system).

Bureau of Land Management

The Bureau of Land Management (BLM) is responsible for 8.4 million acres of land in Colorado, and 262 million acres throughout the United States. Nationally, noxious weeds are increasing on western BLM lands at approximately 2,300 acres per day. In 1994, the BLM's Strategic Plan, "Blueprint for the Future," clearly identified ecosystem health as a high-priority goal. Within this document, "health of the land" and "maintaining or restoring healthy ecosystems," are fre-

quently used phrases. This strategic plan clearly recognized that the greatest obstacle to maintaining healthy ecosystems and restoring impaired ecosystems is the rapid expansion of noxious weeds. These invasive plants can dominate many sites and cause permanent damage to plant communities. In Colorado, noxious weeds have displaced at least 10 percent of Colorado's native plant species and severely degraded important native-plant communities that provide essential habitat to more than 85 percent of Colorado's wildlife species (Lane, 2001).

"Partners Against Weeds, An Action Plan for the Bureau of Land Management" (1996) is the strategy developed by the BLM to prevent and control the spread of noxious weeds. This plan outlines seven goals and actions for implementing a program to control the spread of weeds on BLM-administered lands. Tools such as mapping and inventory are only part of this integrated approach to manage invasive and noxious weeds. From a national perspective, cooperative work with other Federal, State, and county agencies to use the same inventory standards and protocols is highly desired. BLM is already employing the standards developed by the North American Weed Management Association (NAWMA).

Implementing "Partners Against Weeds" in Colorado. BLM strategies for goals 3 and 7 are described below:

Goal 3—Inventory.—Basic inventory for noxious weeds in Colorado is one of Colorado BLM's most urgent needs.

Strategies:

- Determine the distribution of noxious weed species through systematic inventories on all Colorado BLM lands.
- BLM will work with the Forest Service and other agencies in the Department of the Interior to use the same inventory standards and protocols.
- Contribute BLM inventory data to the Colorado Weed Inventory Basemap (CWIB). The CWIB will provide a standard format in which noxious-weed-inventory information can be transferred between various agencies involved in noxious-weed management.

Goal 7—Monitoring, Evaluation, Research, and Technology Transfer.—Comprehensive monitoring programs are necessary to evaluate management activities, providing information necessary for long-term planning and decision-making.

Strategies are to:

- Develop monitoring schemes.
- Develop a BLM Technical Reference on monitoring techniques.
- Include monitoring objectives in activity plans.
- Ensure BLM Land Information System databases are capable of storing, retrieving, and analyzing monitoring data.
- Support research on the ecology, biological controls, remote sensing, and integrated weed management (IWM).
- Contribute to increased funding for biological control research.

U.S. Department of Agriculture— Agricultural Research Service

Although the United States Department of Agriculture—Agricultural Research Service (USDA-ARS) does not manage land holdings, many in the Federal, State, and local communities utilize their laboratories and research findings as a source for reliable information about agricultural practices and impacts on the environment. As the primary research agency in the Department, it is imperative that good partnerships are developed with other agencies and economies be gained from the collaboration between scientists. Most basic science ends at the “proof-of-concept” stage, conducted across small areas. One problem with this approach is that there are usually larger scientific issues that are not addressed when the developed approaches are applied across larger regions. Regional, multidisciplinary, and interagency cooperation is the key to solving this problem. Vast resources and a myriad of technical expertise are needed that no one agency is capable of providing. Therefore, working with other agencies, such as the USGS, provides the USDA-ARS with partners that are highly specialized in natural-resources research, remote sensing/geographic information systems (RS/GIS), and database management. The USDA-ARS can provide specialized equipment and agronomic expertise to the USGS with the operational goal of overcoming regional-scale scientific challenges, while simultaneously focusing on establishing a technical center capable of handling and processing voluminous data to produce usable products for land managers. The technical expertise of our customers varies, and we must be prepared to provide meaningful information that meets specific needs. We cannot assume that our customers will have the resources to meet future RS/GIS and natural-resource-management needs, especially given the rapid change in technology. Therefore, interagency collaborations among agencies—with mission statements ranging from research to product production—are needed to jointly develop comprehensive information-analysis and dissemination systems. A partnership between the ARS and the USGS National Institute of Excellence for Invasive Plant Species Inventory, Mapping, and Monitoring, currently being developed at the Fort Collins Science Center, Fort Collins, Colo., would be a major step toward developing the infrastructure needed to solve complex regional problems and meet customers needs.

Bureau of Indian Affairs

The Bureau of Indian Affairs (BIA) has trust responsibility over 56 million acres of tribal and individual Indian lands, with an estimated 3,295,925 acres infested by noxious weeds. Over the past 12 years, the BIA has been supporting its *Rangeland Noxious Weed Program* with \$1,800,000 available annually for projects treating these noxious weeds on rangeland and pastureland. The primary focus of the program is to leverage the limited BIA funds with matching funds

to control non-native, non-aquatic noxious weeds. There are 11 BIA regions in the lower 48 States, and the regional noxious weed coordinators review projects and make funding selections. The program focuses primarily on rangeland and pastureland, but due to the recognized ecological significance of riparian and wetland habitats, these are included as a secondary focus. The BIA recognizes the importance of cooperative projects and efforts relating to the long-term control and eradication of noxious weeds. Project cooperators include Federal, State, Tribal, and local organizations as well as individual landowners. BIA supports development of a budget initiative aimed at the protection and restoration of native species.

Bureau of Reclamation

The Bureau of Reclamation is responsible for the operation of more than 16,000 miles of canals and 600 reservoirs and dams in the 17 Western States. Reclamation's Technical Service Center (Denver, Colo.) has an Integrated Pest Management (IPM) Research Team within its Ecological Research and Investigations Group (D-8220). Reclamation's IPM team has been actively involved in developing efficient on-the-ground electronic weed-mapping and monitoring methods (with data downloading directly into ArcView) as well as exploring remote-sensing methods. In order to work cooperatively with its neighbors, Reclamation is developing methods for establishing weed management areas where Reclamation has facilities and where such a group does not yet exist. In addition, Reclamation has a strong Integrated Pest Management Program—including a biocontrol program dealing with purple loosestrife, knapweeds, leafy spurge, yellow starthistle, saltcedar, hydrilla, and water hyacinth. Hand-in-hand with the biocontrol projects is a developing vegetation-restoration program.

Each of Reclamation's five regions has an IPM coordinator who works with the area offices within that region. Area offices may or may not have a staff person dedicated to IPM. Projects currently underway include:

- Invasive Species Mapping and Monitoring
 - ◊ Research and demonstration projects focusing on developing efficient on-the-ground invasive-species-mapping techniques using hand-held computers connected to GPS's. Data collected on foot, on ATV or other vehicles can be downloaded into ArcView.
 - ◊ Research and demonstration projects focusing on developing efficient invasive-species remote-sensing-mapping methods using color and color IR photography as well as multispectral scanner or satellite imagery.
 - ◊ Research and demonstration projects developing practical monitoring methods to determine efficacy of invasive-species-control methods to use as a planning tool.

- Restoration Following Control
 - ◊ Conducting intensive research and restoration activities for numerous areas in the Western United States, primarily focused on the restoration of saltcedar control areas utilizing certified seed in revegetation efforts.
 - ◊ Working on development of draft comprehensive “weed-free” policy on Reclamation revegetation projects, including requiring adherence to State seed laws on Reclamation-managed lands. Conducting research on types of native seeds that could best be used in revegetation projects and yield successes that could support such a policy affecting most/all revegetation projects.
 - Biological Control Focus
 - ◊ Biocontrol research utilizing the saltcedar control beetle *Diorhabda elongata*.
 - ◊ Have established biocontrol projects to reduce/eliminate the use of herbicides. Insect biocontrols are being used on purple loosestrife, saltcedar, leafy spurge, yellow starthistle, and knapweed, hydrilla, and water hyacinth. Herbicide savings from using biocontrol insects on loosestrife in the Columbia Basin Project (Washington State) totaled \$840,000 in just 1 year.
 - ◊ Grass carp are being successfully used to control aquatic weeds in many irrigation systems. Use of this fish saves the Central Arizona Project (Arizona) \$1 million/year, and more than \$1 million/year in the Imperial Irrigation District (California) over herbicidal and mechanical methods.
 - ◊ Staff participation on the Technical Advisory Group for Biological Control Agents of Weeds, which conducts petition reviews for the use of weed-specific biocontrol agents.
 - Agency and Public Outreach
 - ◊ In conjunction with establishment of Cooperative Weed Management Areas (WMA's), Reclamation is conducting invasive/noxious weed mapping utilizing GPS and GIS technologies. Part of this effort is being carried out in cooperation with State and private weed-mapping programs that are designed to monitor invasive populations and actions taken to control those populations.
 - ◊ Developing an IPM manual for field staff for management on Reclamation facilities and lands.
 - ◊ Cosponsored “Plant Management Information System” (PMIS) CD-ROM with U. S. Army Corps of Engineers.
 - ◊ Developed and published posters and brochures for hydrilla (in English & Spanish) and Eurasian Water Milfoil, showing identification features of these invasive aquatic weeds while explaining the damage these species do to native aquatic plants and their habitats. Also, developed traveling displays explaining the threat to native terrestrial plants and aquatic plants/fish from, respectively, purple loosestrife, and zebra mussels.
 - ◊ Designed and produced zebra mussel and aquatic weeds signs for boat launch ramps at Reclamation-managed reservoirs. These signs instruct the public about the risk of inadvertent transport of these pests.
 - ◊ Cosponsored saltcedar management conference, with more than 200 attendees.
 - ◊ Contribute to Westminster Water District (Colorado) Eurasian Water Milfoil Workshop for Denver Metropolitan Water Managers.
 - ◊ Hold annual Reclamation Integrated Pest Management Workshop.
 - Other Activities
 - ◊ A special patented herbicide-metering system delivers exact parts per billion doses of herbicides to flowing water—even as canal flows fluctuate, reducing herbicide costs and environmental damage from “overdosing.” Use of this system could potentially save the Salt River Project (Arizona) \$140,000/year on herbicides.
 - ◊ As part of the work of the Colorado River Giant Salvinia Task Force, Reclamation staff conducts periodic surveys to monitor growth and spread of *Salvinia molesta* in the lower Colorado River Basin of the Southwestern United States.
 - ◊ Technical staff participates in several State and local committees, including active participation in the Colorado Noxious Weed Committee. Staff has contributed to development of the Colorado State strategy document for invasive species.
- Funding for projects comes from Reclamation's Science and Technology Program, the Office of Policy, the Regions and area offices, as well as local project cooperators, including other Federal agencies. Funding on research and demonstration projects is generally leveraged a minimum of 3:1.

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Appendix A—Results from Breakout-Group Discussions

The purpose of breakout groups was to develop a base of detail and knowledge for each topic (inventory, mapping, and monitoring) that will help focus the identification of the need and the development of the proposal. Following is a list of questions discussed during the breakout topic group.

1. Discuss the justification for the need of your topic followed by objectives the group wants met.
2. Discuss the role of standards, what already exists, what standards would be needed, and will they be accepted and useful across all land-management agencies (be sure to discuss classification standards and data-collection standards).
3. Discuss procedures and methods applicable to your topic that would provide the most useful information.
4. Discuss what products are most important and useful.
5. Discuss research needs for the topic.
6. Discuss the role of models in your topic.
7. Finally, discuss potential collaborative activities (for example, what role can the agency field offices play, what capabilities exist that can be leveraged, what programs can be combined).

Inventory Breakout Group

Definitions

- *Inventory*—Creating the baseline information on a designated area (what you have, where it is located, and at what point in time) including metadata. Information should be collected about the physical (site conditions), what invasive species are present, population estimate (degree of infestation), and community associations.
- *Monitoring*—The repetitive updating of the inventory and follow-up on treated areas, quantifying changes to the baseline information.

1. Justification and objectives for inventory

- If we are to have an effective management program, first we must have fundamental baseline information

for future monitoring and management planning and effective resource spending.

- Economic impact of invasive populations on the United States (\$138 billion)
- Ecological impact on ecosystem services (e.g., clean air, clean water, pollination, recreation, aesthetics, erosion control, and biodiversity).
- Economic valuations of these impacts are poorly understood and less tangible. Scientific studies are needed to establish the cost.
- Because of the explosion of invasives, a baseline must be developed now. Question such as what do we have now, in what way is it changing? Vectors for invasion, etc., on invasives coming into the United States.
- The United States is also exporting species into other countries. What is the impact on global trade?
- Limitations on future land uses and sustainability (future productivity, grazing vs. housing).
- Do this to support the Executive Order, the National Management Plan, and the National Invasive Species Council. Interaction with State and local legal requirements and mandates, including supporting trust species and trust lands.
- Better baseline for management alternatives (information for adaptive-management decisions and policy development).
- Baseline information helps to identify and focus research needs.
- Research application—qualitative, “quick-and-dirty” application of research results. “We can’t wait for a 2- to 5-year peer review publication period. What can we do next spring?”
- Information and technology/applications transfer to management as research continues, also get management feedback to researchers on goal and objectives.
- Education and awareness

2. Role of standards, what already exists, what standards are needed

- Role—The role of standards is to facilitate comparison, contrast, synthesis and communication of information collected by many people in various places and time frames.
- Existing National Standards
 - ◊ North American Weed Management Association (NAWMA) Standards—many agencies and States have already established this as the *minimum* core-data standard.
 - ◊ There are additional ecological and environmental parameters important in the inventory of invasives—information should be collected about the physical (site conditions), population estimate (degree of infestation), and community associations.
 - ◊ Federal Geographic Data Committee (FGDC) standards for metadata and mapping are relevant.
 - ◊ Integrated Taxonomic Information System (ITIS) nomenclatural standards.

3. *Discuss procedures and methods applicable to inventory*

- There is no single protocol that you can apply to the inventory of invasives.
- Protocols will be driven by the objectives and goals of the manager/researcher (via good lines of communication) deciding what data is needed and how managers and other users intend to use the data above and beyond the core minimum requirements.
- Make sure that basic science (i.e., species biology and ecology) is a part of what we do, in addition to the applied research required by our partner agencies.
- Explore cutting-edge technologies, appropriate use of existing technologies (remote sensing, for example).
- Establish protocol or procedures beyond jurisdictional boundaries to involve all stakeholders, including communications with local landowners, and expand beyond regional and agency boundaries.
- Explore protocols for early detection.

4. *What products are most important and useful?*

- Research application—qualitative, “quick-and-dirty” application of research results. “We can’t wait 7 years. What can we do next spring?”
- Public education: product brochures, internet sites, waysides.
- Integrated web information.
- Providing usable products that answer the questions of the managers.
- Protocols or operating systems for early detection of invasives.
- Database of agencies involved in active management of different species. What agencies/contacts have ongoing species-by-species management practices?
- Database of invasive species occurrences.
- Creation of a distributed, querying, database system for invasive species collections/specimens; North American Biodiversity Information Network (NABIN)/Species Analyst
- Protocols for specific, simple methods that can be applied, given a reasonable amount of information.
- Distribution maps of species, ecology of species, what we know about reproductive methods, and how it spreads.
- Pulling together identification aids and providing broad access to them.

5. *Discuss research needs*

- Be aware of and ensure two-way communication between researchers and land managers.
- Capital S Science—research, develop, and make available basic science on invasive species (a species-by-species process).
- Develop information about ecosystem susceptibility to invasives
- Ecosystem and population dynamics models must be developed further.
- Further develop and use remote-sensing technologies.
- Identify protocols for sampling design and statistical

strategies to better locate invasive species.

- Potential ecological range studies—for example, if a new invasive species is discovered, what is the potential for spread?

6. *Role of models in inventories*

- Critical for determining susceptibility, predictability, early detection, and for the effective and strategic use of limited resources.
- Adaptive-management models/tools and decision-support systems and tools.
- Invasive species response to environmental perturbations and management practices.
- Use models to focus research and inventory efforts.

7. *Discuss collaborative activities*

- This is extremely important and must be kept in the forefront in everything we do.
- Currently there is little across-agency collaboration and communication about invasive-species research and control projects.

Summary

An inventory (taxonomic and geographic) of invasive plant species is important to establish a baseline of the status of the problem. Which plants are out there, how many (cover or acreage), what native vegetation communities are being affected, etc. A standardized approach would allow for a national assessment of the status of the situation.

Mapping Breakout Group*Justification and objectives for mapping*

- There is a national outcry for the maps that depict current information on locations and predictions of where invasives will spread. Spatial data identifies locations on landscape so management action can be taken.
- Resource managers are looking to solve the problem. Managers need to know baseline, trend, and what to expect for the future. Tools will follow these objectives.
- Mapping is needed at a variety of scales, from national picture for Congressional information to site-specific local information useful for land managers.
- Must be able to use the product on the ground.
- Information requirements include where invasives are now, where they may spread, and how much damage is being done and the effectiveness of management actions.
- Mapping must be rapid and the products developed by mapping must be simple to use. Data developed by mapping must be useable in GIS
- Need to integrate science with what pest manager needs. Developing predictive capability is essential.

Role of standards, what already exists, what standards are needed

- Standards are critical. Everyone says they want standards, but they are doing things differently.
- Need protocols and standards for collection of data,

location recording and accuracy, databases, metadata, taxonomy, and data-file exchange.

- Use existing standards as appropriate, e.g., NAWMA, FGDC, IT IS, etc.
- Standards must allow data to be rolled-up to address broad-scale problems.
- Focus standards on the information needs.
- Standards will be continuously evolving.
- There are many databases—perhaps 20 to 100 within each agency. Need to standardize within each agency as a first step.
- Accuracy is not overwhelmingly important, but rapidity is very important. Need to determine an appropriate level of accuracy for the information needs or metadata to classify level of accuracy.
- Manager and biologist perspectives are different. What is minimum level of accuracy for thematic and locational data for different users.
- Long-term data are important to tracking trends.

Procedures and methods applicable to mapping

- Managers have problems and we need to address those problems. Procedures and methods have to be approached from this standpoint.
- Need to be flexible with standards and use common sense.
- Different plants require different standards and approaches.

What products are most important and useful?

- Can we solve some of these problems without mapping? We can go back to plots and simply resurvey using the plots. If no baseline plots, can the manager solve his problem without a map? Depends on problem.
- Field-level need is to find and kill. Can this be done without map? Yes. Then do we need to map not where it is but where it is not? Also, need to map where lands have been treated.
- For complex issues, need to document it with a map and where you are going.
- In USGS-NPS Vegetation Mapping Program there are ancillary data collected at the site, which may be useful in the long run.
- Once have baseline, how often do you update the base map? Need same scale resolution and accuracy? May need to look at some other technologies. Not enough money to do it all at the same level.
- There are resources managers who will tell you they do not need maps. When new person (manager) comes on board they have nothing to work with. Aerial photograph may be all they need.
- There are longer term research needs to start looking at the ecology.

Role of research

- Must know species dynamics, potential spread, where it is from where you are, where is it in the ecosystem, what is the risk to the ecosystem if it is on the outside?
- Need to communicate needs from managers to those

who have the resources (e.g., NASA) and can “make a better hammer.”

- National weeds conference has science theme in 2004.
- Need to reduce the cost of inventory and mapping to 50 or 25 cents an acre. Need faster and cheaper, which are more important than better.

Role of models

- Essential to predict which areas are susceptible to invasion and rates of spread. Mapping by itself does not meet this need.
- Model may tell you if the invasives are already there, but ground verification is a must.
- Species dynamic should be drawn into the model. Integrate and understand species dynamics from other areas and not do basic research on species dynamics.
- Need to understand landscape dynamics. Every time we release a cow or have prescribed fire we are changing the land but we do not know how. Vulnerability of land goes hand-in-hand with invasive species.
- What happens to invasive species when we burn. We need to know how species are enhanced or depressed.

Collaborative activities

- Managing as a system is not being effectively done right now. Institutional and regional turf are issues. Agency comprehensive management plans have to be integrated to address invasive issues.
- Education is critical. Agency staff at all levels will have to be educated on the importance of invasives and the tools, standards, and protocols that are being developed to address invasives.
- Multiple agencies need to support this budget initiative. We need to engage bureau budget shops and we need other agencies to move proposal up through their organizations at the same time so all the agencies are talking about the same thing at the same time.

Summary

Mapping is not new and is being done using a variety of tools, formats, and applications. A coordinated, standardized approach would be beneficial from a national perspective, but due to the different missions of Federal land agencies, care must be taken in adopting or developing the standards to be used. Map products must be a standard format and usable for analysis, integratable with other spatial data, and of sufficient quality to be used in development of predictive models. Knowledge of vegetation communities, including invasives, that are on adjacent agency lands will help prioritize management actions, develop predictive models, test and monitor management actions, evaluate controls, anticipate movement and vectors of invasive plant movement to serve as early warning.

Monitoring Breakout Group

Justification and objectives for monitoring

- Monitoring needed to help decide if management actions are working.

- Existing laws and mandates.
- Critical for early detection.
- Determine effectiveness of treatments and restoration actions.
- Monitor controls on non-target species (native species).
- Raise awareness of importance of monitoring.
- Meet land-management goals.
- Evaluate effects of treatments.
- Data for adaptive-management applications.
- Agency mandates may vary:
 - ◊ NPS—I&M guidelines and a mandate to protect native species.
 - ◊ BLM—rangeland health.
 - ◊ FWS—T&E species protection, habitat protection.
 - ◊ FS and National Grasslands—to protect native species.
 - ◊ Interaction with adjacent public and private land managers.

Role of standards, what already exists, what standards are needed

- Need some flexibility, but also need to consider the importance of comparability.
- Mapping standards set stage for monitoring.
- Ultimate result must be useful to field managers.
- Need for consistency.
- Coordination across agencies and State and private landowners and managers.
- Look for overlap with other monitoring activities.
- Take advantage of existing standards:
 - ◊ Mapping standards.
 - ◊ Plot and transect standards.
 - ◊ NAWMA standards.
 - ◊ Nomenclatural standards.

Procedures and methods applicable to monitoring

- Driven by land-management objectives.

- Must meet land managers' goals.
- Also meet regional and national priorities.

What products are most important and useful?

- Provide guidelines for managers.
- Decision support systems.
- Provide training opportunities (team approach).
- Ancillary data (soil, fire, and other disturbance) all important for modeling aspects.
- Model products—data from other organizations can help predict what may be coming in (early detection).

Role of research

- Analyze bias in data.
- Restoration techniques associated with control and treatments.
- Effects of biological controls.
- Effects on non-target species.

Role of modeling

- Identify where to monitor based on predictive models and where to add monitoring sites (iterative approach).
- Include economic modeling.
- Risk assessments and priorities.
- Predictive models—at land-manager site-specific resolution.
- Change detection.
- Predictive spatial/temporal models—where and when will invasives occur.

Collaborative activities

- Share data and monitoring information.
- Volunteers can play a role (look at existing systems, some on the web).
- Baseline information, early detection.
- Build political constituency.
- Leverage other monitoring efforts (fire, forest health.)
- Different levels of need (ecosystem vs. site-specific).
- GPRA goals.

Appendix B—Workshop Participants and Report Contributors

Name	Agency	Name	Agency
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